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**PL-TR-92-2326**

**OPTICAL MEASUREMENTS OF NASA/USAF CRRES  
HIGH ALTITUDE ROCKET BORNE CHEMICAL RELEASE  
EXPERIMENTS IN CONJUNCTION WITH THE USAF  
AIRBORNE IONOSPHERIC OBSERVATORY AIRCRAFT**

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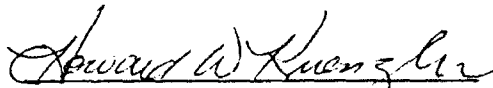
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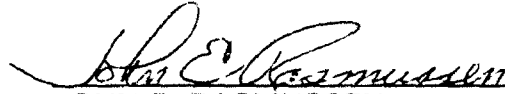


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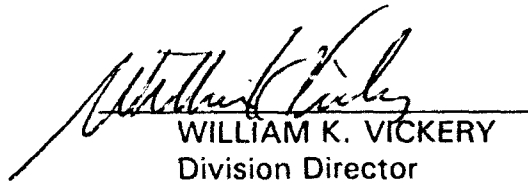
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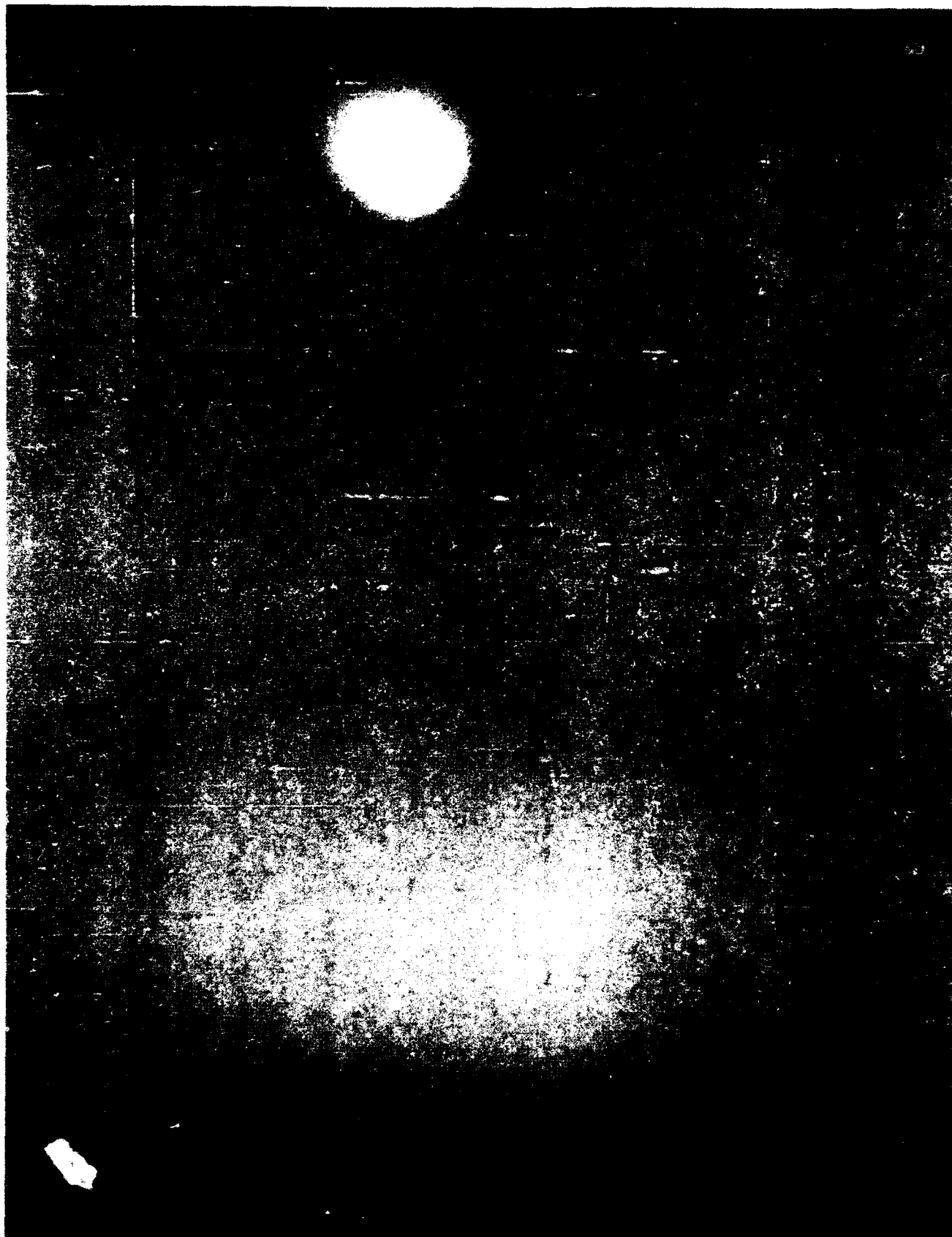
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## INTRODUCTION

The study of the evolution and decay of structural irregularities of high altitude ionospheric plasmas together with the dependence of this structural evolution on the underlying E-region electrical conductivity and E-region images of this structure is the focus of the PL participation in the NASA/USAF CRRES research program for 1992. The naturally occurring ionospheric irregularities can be studied, it is believed, by observing the influence of a large artificial chemical vapor release in this ionospheric region at morning twilight in conjunction with the increasing solar atmospheric photoionization to lower altitudes with the occurrence of sunrise. The study of the conductivity of the disturbed ionosphere will be attempted by performing amplitude and phase scintillation measurements on a satellite signal passing through the changing structured region to receivers in the PL/AIO aircraft tracking the satellite signal from below. In support of the airborne project measurements, TIC will record optically from a suitable ground site the growth, motion, and any visible structure of the chemical release cloud for subsequent correlation with the aircraft satellite measurement data.

### Background

The use of experimental controlled chemical releases in the earth's upper atmosphere to study the effects of both locally induced geophysical perturbations and long term background conditions is a scientific technique of long standing. Typically a metallic vapor such as barium, lithium, sodium, or samarium is released in a sunlit environment in the ionosphere. The incident solar UV radiation will continually ionize a portion of the neutral atoms evolving an ion cloud in addition to the initial neutral cloud. Both the ionized and remaining neutral atoms of

the vapor cloud are visible as a consequence of UV absorption and visible emission from each excited atom. Under conditions of high column density along a particular line of sight the clouds may be optically thick to visible radiation and an observer is in effect seeing only to a limited depth of several optical mean free paths under such circumstances.

The weak (singly ionized) ion cloud plasma will field align and often structure as a consequence of plasma instabilities and other external forces, imitating natural auroral occurrences to a degree. This structured -- generally slow moving in mid-latitude regions-- plasma provides a geophysical condition on demand for which specific observational or interactive experiments can be planned and carried out in conjunction with ground, aircraft, and satellite observation sites and platforms. The residual neutral cloud motion will, over time, trace out the ambient neutral winds providing additional data of interest in correlating the phenomenology of the overall experiment. In general, small chemical releases of the order of one kg or so will be suitable for examining natural ambient ionospheric forces whereas large chemical releases of tens of kg chemical yield such as CRRES-Caribbean will disturb and affect the natural environment providing an expanded experimental base for study.

#### Project Summary

In order to view the faint optical solar resonance scattering emissions from the neutral and ionized metallic vapor releases in the ionosphere, it is necessary that the ground (and/or airborne) observation sites be initially in a degree of local darkness such that the angle of solar depression below the local horizon is --ideally-- between about  $12^{\circ}$  (nautical twilight) and  $18^{\circ}$  (astronomical twilight) for optimum coverage.

During an evening twilight experiment a release cloud will gradually emit less radiation as the increasing earth's shadow height passes through the cloud volume with sunset. During a morning twilight experiment, the rising sun lowers the shadow height but increases the visible sky background emissions to where, eventually, the cloud cannot be distinguished against this background. Thus both dusk and dawn twilight can be equally suitable for obtaining the necessary background conditions depending upon the temporal extent of the experimental requirements.

The revised PL CRRES experimental plan called for three rocket borne ionospheric release experiments in the Caribbean in the late spring of 1992. The releases will be relatively large yield (50-80kg) barium thermite reactions at an altitude of approximately 250km over the Arecibo ISR, launched by rockets from the north coast of Puerto Rico. The PL experiments were to be observed by the PL Airborne Ionospheric Observatory (AIO) and required a ground based site to provide optical phenomenological and motion measurements support as part of the experiment for each of the three launches. TIC deployed and operated the required optical site for PL in the western Caribbean as part of the PL experimental measurements program.

Given the pre-condition that the CRRES-Caribbean rocket launch experiments were to be conducted as morning twilight releases, the TIC/PL ground optics instrumentation was planned to be located as far to the west of the release as practicable. By locating as far west as possible the release could be viewed longer against an increasing sky background as sunrise occurs. The limitations as to how far west a station can be located is dictated by the line of sight (LOS) elevation to the release. This elevation angle should generally be no less than



20 degrees for a sea level or similarly situated observation site.

With Puerto Rico established as the launch site for the CRRES-Caribbean campaign, there were relatively few potential observation site locations in the western Caribbean which met the above criteria. Initially the island country of the Dominican Republic was chosen for the TIC ground site location. The desired alternative for logistical and support considerations was the U. S. Navy Base at Guantanamo Bay, Cuba, but the LOS elevation angle was insufficient. A site survey trip to the Dominican Republic in the spring of 1991 by one TIC and one PL representative established that --all factors considered-- it would be difficult to establish a suitable site within a reasonable distance of lodging and transportation access for the planned instrumentation van.

Subsequent to the Dominican Republic survey trip, the NASA CRRES-Caribbean program was delayed for what would develop into a one year delay. In the interim other CRRES-Caribbean experimenters had established that the island of Grand Turk, to the north of the Dominican Republic, was in all likelihood going to be made available by the British government for the NASA sponsored program. In coordination with LANL and NASA/GSFC experimenters TIC determined that Grand Turk would be a suitable site for the TIC/PL optical experiment and that course alone was pursued for the rescheduled 1992 program. In consequence of the changes in schedule, site location, and transportation availability a revised ground optics instrumentation plan was developed for the three PL experiment. This revised plan is incorporated into this report in a later section.

Assistance in obtaining equipment transportation, customs clearance (both British and return U.S.) and experiment authorization in Grand Turk was provided by the Air Force Logistics and Field Operations Branch at L. G. Hanscom AFB. The ground optics equipment was

deployed in late May and set up for operation on Grand Turk in the latter part of June. The CRRES-Caribbean operation commenced on 30 June 1992.

## INSTRUMENTATION

In order to record the morphological development history of each of the NASA/PL bannam releases, a complement of faint phenomena cameras was set up and tested for use on the CRRES-Caribbean program prior to shipment to the field. Camera instrumentation was chosen to optimize the objective optics and film format to provide a balance between spatial resolution and field of view in conjunction with data record cycling rate, run duration, and film type. Typically, a chemical release at twilight in the earth's ionosphere can be viewed for a period of between 20 to 40 minutes depending upon specific geophysical and experimental parameters. Photographic exposure durations for unfiltered camera systems will vary from 4 to 16 seconds and the film load capacity of the individual instrumentation must accommodate this cycle rate and experiment duration.

In addition to selecting the proper optical instrumentation for a chemical release program, it is necessary to utilize instrumentation mounts which will provide both stability for long data exposures and a readily adjustable and calibrated pointing capability for pre-pointing of the camera systems and collateral read out between mounts when required during release tracking operations.

Appendix A presents the revised TIC optical Instrument Plan for the CRRES-Caribbean experiment as conducted in July 1992. The primary instrument system (position 11) was a sequencing electrically operated camera with a field of view of somewhat more than 30 degrees. This camera, using high speed color film, was capable of operating for the order of 40 minutes or more when sequenced at a rate averaging over 10 seconds per exposure. A back up to the primary camera was also provided (position 14) and integrated to the same photo theodolite

camera mount (KTH-1).

In the event striations occurred in the chemical ion cloud a long focal length (230mm) high resolution camera system was also provided. This camera (position 12) was manually operated at one minute intervals throughout the release and was mounted on an second photo theodolite camera mount (KTH-2).

Finally, an electrically operated 35mm camera was provided (position 13) to enable the experimenters to process film between events locally so as to be able to review a given events characteristics prior to a succeeding experiment.

## OPERATIONAL PROCEDURE

The TIC optical instrumentation, mounts, and support equipment were shipped to the field from TIC Bedford in early June. The equipment travelled over the road to Miami and from there to Grand Turk by container ship on 15 June. Although the ground optics site was originally scheduled to be located at the former Smithsonian Marine Biology Building compound situated on the eastern shore of the island, that location proved impracticable for various reasons and a more suitable site was identified with a good eastward view and logistical support base. A phone line was immediately installed upon arrival at the TIC/PL ground site. Within a few days the camera instrumentation mounts were set up and calibrated for azimuth and elevation; cameras were then added to the mounts. The communication net system was inaugurated in late June and was ready for the pre-event check out activities several days prior to the first launch. Throughout the early arrangements and site installation the British government and local authorities were most helpful.

The three CRRIS-Caribbean chemical release experiments were conducted in early July 1992. The two experiments most strongly associated with the aircraft-satellite observations, AA-1 and AA-7, were performed on 2 July and 4 July 1992 respectively. The third release experiment, AA-2, was performed on 12 July 1992. The release operational parameters are presented in Table 1, as made available by PL/GPIA. In all cases the rocket experiments were launched from Vega Baja on the northern coast of Puerto Rico, and programmed to fly out at an azimuth of approximately  $320^{\circ}$  true. A map of the ground projection of the Black Brandt V planned rocket launch trajectory prepared by PL/GPIA is presented in Appendix B.

Launch scheduling and count-down information was communicated to the TIC Grand Turk and other optics sites by a NASA controlled teleconferencing network originated at Arecibo, P. R.. Two way communication over this net permitted the project technical coordinator to assess weather conditions throughout the various optical sites comprising the Caribbean wide site network several times throughout the period preceding each morning twilight experiment.

The launch and therefore event time for a given experiment date was determined with primary consideration of the solar depression angle (SDA) at the release point at altitude. A launch window incorporating a narrow tolerable variation in SDA was established for each day of the overall July two week moon down window period. The first experiment was launched late in the 2 July morning window as can be seen from reference to Table 1.

Weather conditions at launch time varied considerably at the Grand Turk optics site for the three PL experiments. The Grand Turk weather (and cloud formations in the direction of the event) for the first event (AA-1) was reasonably clear for most of the coverage period. Weather (i. e. clouds) for the second event (AA-7) was good for only a portion of the optical coverage period from Grand Turk; for the third event (AA-2), the weather was completely overcast from the TIC/PL site.

For future reference the geographical coordinates of the three NASA/PL CRRES-Caribbean releases together with the surface coordinates of the Grand Turk optics site are contained in Appendix C.

TABLE 1

## CRRES-Caribbean Launch Parameters

<u>Date</u>	<u>Event</u>	<u>Launch</u>	<u>Release</u>	<u>Altitude</u>
2 July 1992	AA-1 48 kg Ba payload*	09:01:12	t + 141 sec	254.9 km
4 July 1992	AA-7 48 kg Ba payload*	08:58:00	t + 141 sec	253.7 km
12 July 1992	AA-2 80 kg Ba payload*	09:02:00	t + 151.9 sec	252.5 km

SOURCE: D. Kotsifakis communication, 9-1-92

\* Comprising all components prior to thermite reaction

## RESULTS

The ground optics instrumentation operated flawlessly for the first two events and with one secondary camera malfunction during the third experiment. As alluded to earlier, the local weather and cloud cover in the experiment field of regard together also with eventual sunrise background were the limiting factors as to what data could be acquired and for how long.

Experiment AA-1 was observed from release until approximately R+23 minutes. The 255 km altitude release expanded to an apparent maximum initial diameter within approximately 1 minute. Cloud edge hardening was first observed from primary camera data at about R+112 seconds. The field aligned pinkish colored ion cloud appears to reach a maximum elongated dimension approaching 96 km at about 13 minutes after release. No clearly definable striations were observed from Grand Turk for the AA-1 event.

Figures 1 through 3 show the development of the AA-1 metallic vapor cloud over a 9 minute period. Figure 1 shows the cloud at approximately R+8 seconds having reached an observed\* diameter of 43 km\*\* at this time. Figure 2 shows the cloud at approximately 64 seconds with an expanded diameter of 83 km, which corresponds to the maximum value recorded for the AA-1 event as seen from Grand Turk. Figure 3 shows the classic shaped field aligned hardened edge ion cloud at R+9m 20s. The star field in the background of this data is CETUS and ERIDANUS.

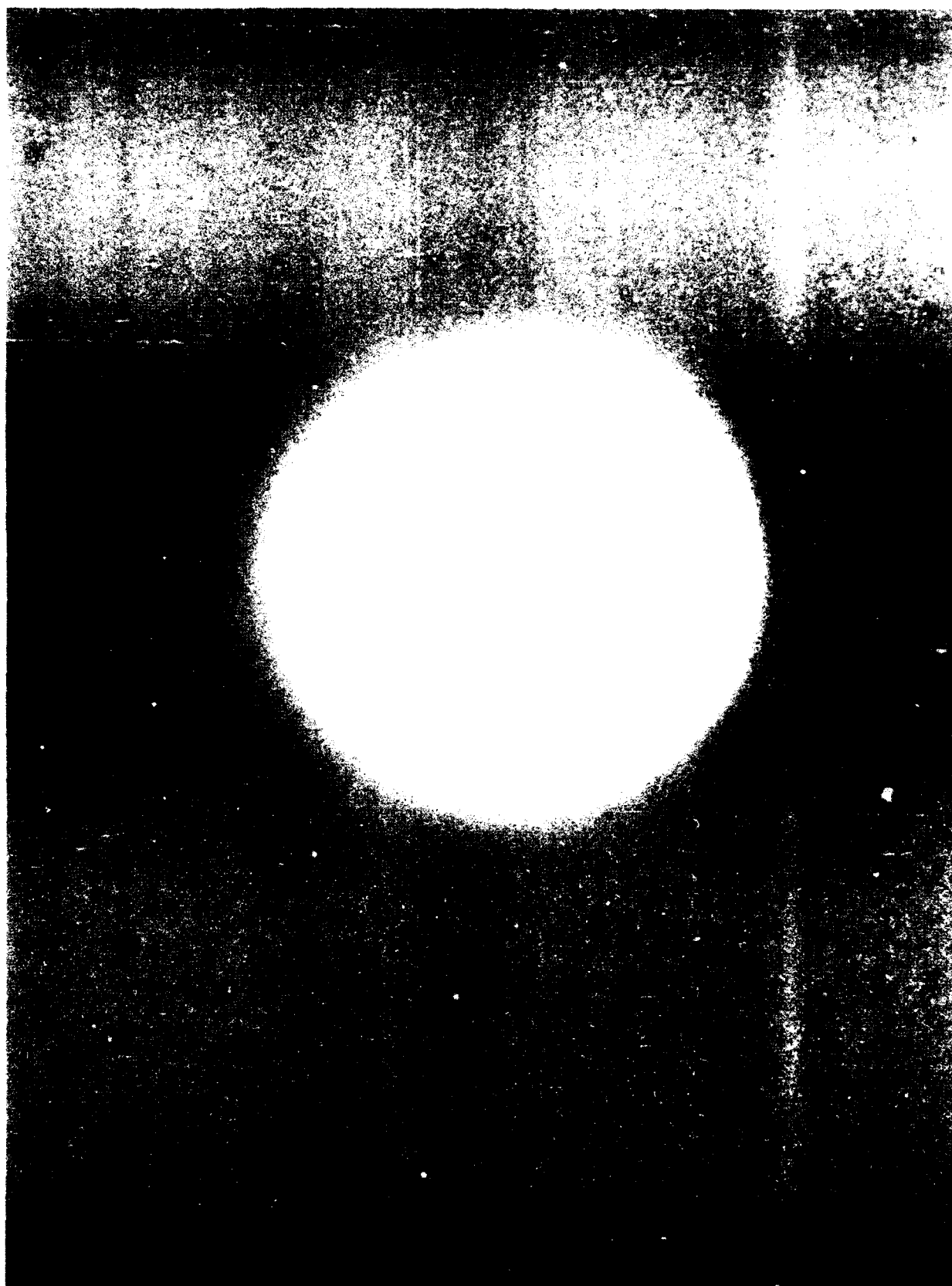
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\* Based upon a calculated initial (and constant) slant range of 628 km from Grand Turk to the release point.

\*\* This value is significantly greater than the 30 km diameter observed in the 48 kgm REDWOOD I event from Project SECEDE II. The fact that the current boron-titanium thermite reaction burns hotter, faster, and expands more rapidly than the previously used cupric oxide thermite mixture is consistent with the observations.









1. The first part of the document is a list of names and addresses of the members of the committee.

The AA-7 event was observed for approximately 24 minutes from Grand Turk, albeit intermittently due to passing cloud formations. The general shape of the mature AA-7 cloud was much the same as the AA-1 cloud, and as with AA-1 did not show any indication of structural striation during the visible observation period. Figures 4, 5, and 6 show the AA-7 cloud from Grand Turk at time of R+5m 32s, R+9m 32s, and R+16m 17s respectively. The maximum apparent dimension of the cloud in figure 5, from lower left to upper right, (parallel to the hard edge) is approximately 102 km at this time. The AA-7 cloud does not appear to have drifted significantly during the times shown in these figures. The same star field background as was seen in the AA-1 data exists in the AA-7 data. The CETUS and ERIDANUS constellations are shown in Appendix D for spatial reference.

Figure 4. AA-7 (left), R = 0 minutes, 32 seconds; TIC Record No. 77614-24.



Figure 1. A Total Ion Chromatogram (TIC) plot showing detector response over time. The x-axis represents time in minutes, ranging from 0 to 100. The y-axis represents detector response. A single, sharp, prominent peak is visible at approximately 32 minutes, reaching a maximum response of about 1.0. The baseline is relatively flat with minor noise. The plot is labeled "TIC Record N 100" in the top right corner.



1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100.

APPENDIX A

TIC CRRES-CARIBBEAN INSTRUMENT PLAN



# TECHNOLOGY INTERNATIONAL CORPORATION

## INSTRUMENT PLAN

OPERATION: CRRIS-C DATE: July 1992 STATION: Grand Turk Island  
EVENT: AA-1, AA-7, AA-2 LOCATION: P. R. Launch PROJ/ENGINEER: TIC/PL/NASA

| POSITION | INSTRUMENT   | FOCAL LENGTH  | FILTER | FILM                               | f/n | SHUTTER/RATE           | REMARKS         |
|----------|--------------|---------------|--------|------------------------------------|-----|------------------------|-----------------|
| 11       | CA-120E (N)  | 98mm          | ---    | 2253 E-400<br>70mm x 100'          | 1.4 | 8, 16 sec<br>program A | 32x32° KTH 53-1 |
| 12       | PE 9         | 9"<br>(230mm) | ---    | 2253 E-400<br>70mm x 18'           | 1.5 | 10 sec<br>manual       | 14x14° KTH 53-2 |
| 13       | N-2000       | 85mm          | ---    | 5110 C-1000<br>35mm x 24 exp<br>** | 1.4 | 10 sec<br>manual       | 16x24° KTH 53-2 |
| 14       | EI-500 (MOD) | 110mm         | ---    | 2253 E-400<br>70mm x 18'           | 2.0 | 16 sec<br>program B    | 29x29° KTH 53-1 |

ADDITIONAL INFORMATION: the pre-loaded space to be provided (each capable of recording 2 events).

alternate- Verticolor C-400

PERF Nos.: 775XX, 776XX, 777XX

APPENDIX B

CRRES-CARIBBEAN PLANNED  
ROCKET LAUNCH TRAJECTORY

03/16/92

TERRIER-BLACK BRANT VC 36.082 DE

483.° P/L. 85.0 OE. 325. AZ. PR

3 SIGMA = 149 X 119 KMS RADIUS

|            | LATITUDE | LONGITUDE |
|------------|----------|-----------|
| IMPACT =   | 20.4332, | -68.1169  |
| LAUNCHER = | 18.4903, | -66.4400  |
| RADAR =    | 18.3462, | -66.7529  |
| RELEASE =  | 18.8608, | -66.7430  |

1. 2. 3 SIGMA • RELEASE

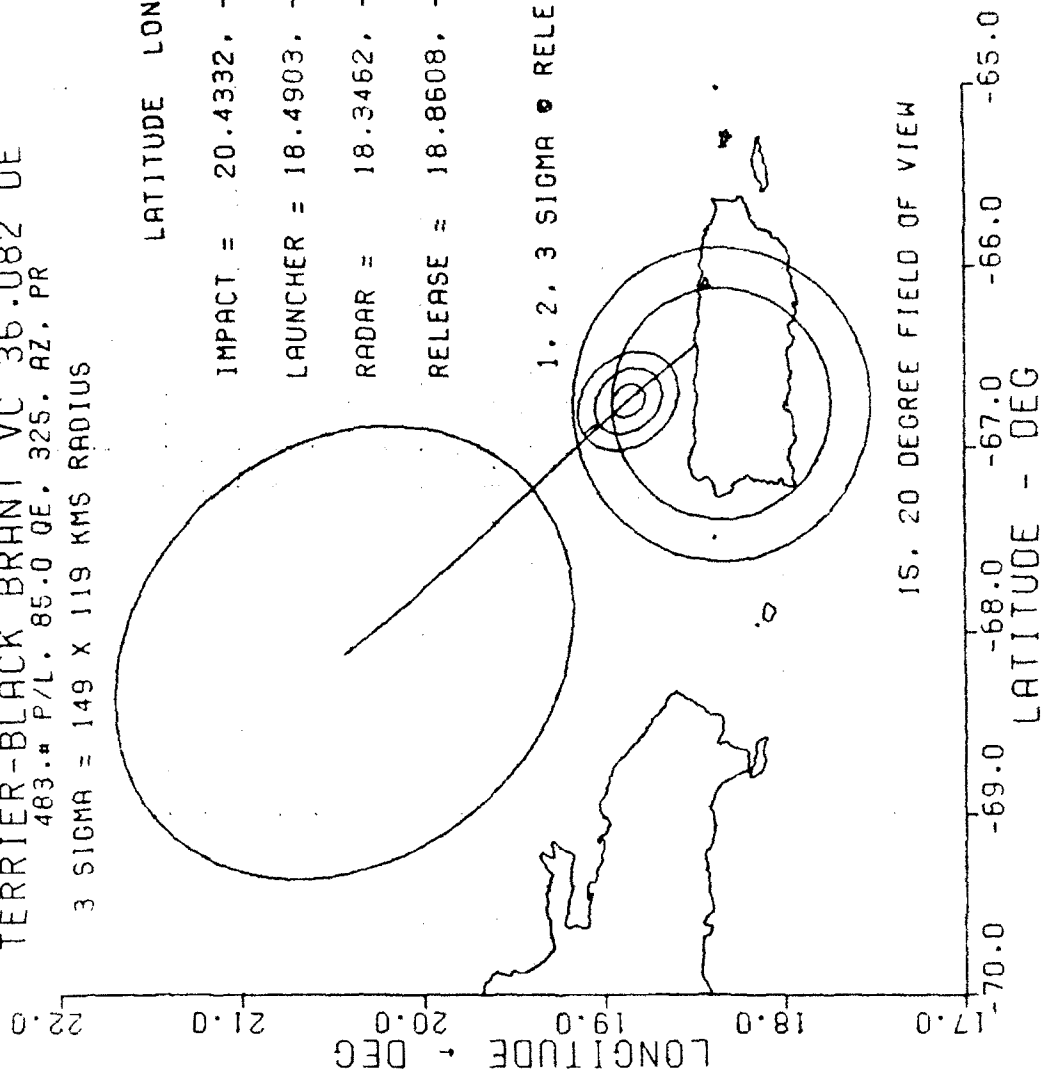


FIGURE 6-1. PUERTO RICO MAP

APPENDIX C

CRRES-CARIBBEAN GEOGRAPHICAL  
COORDINATES

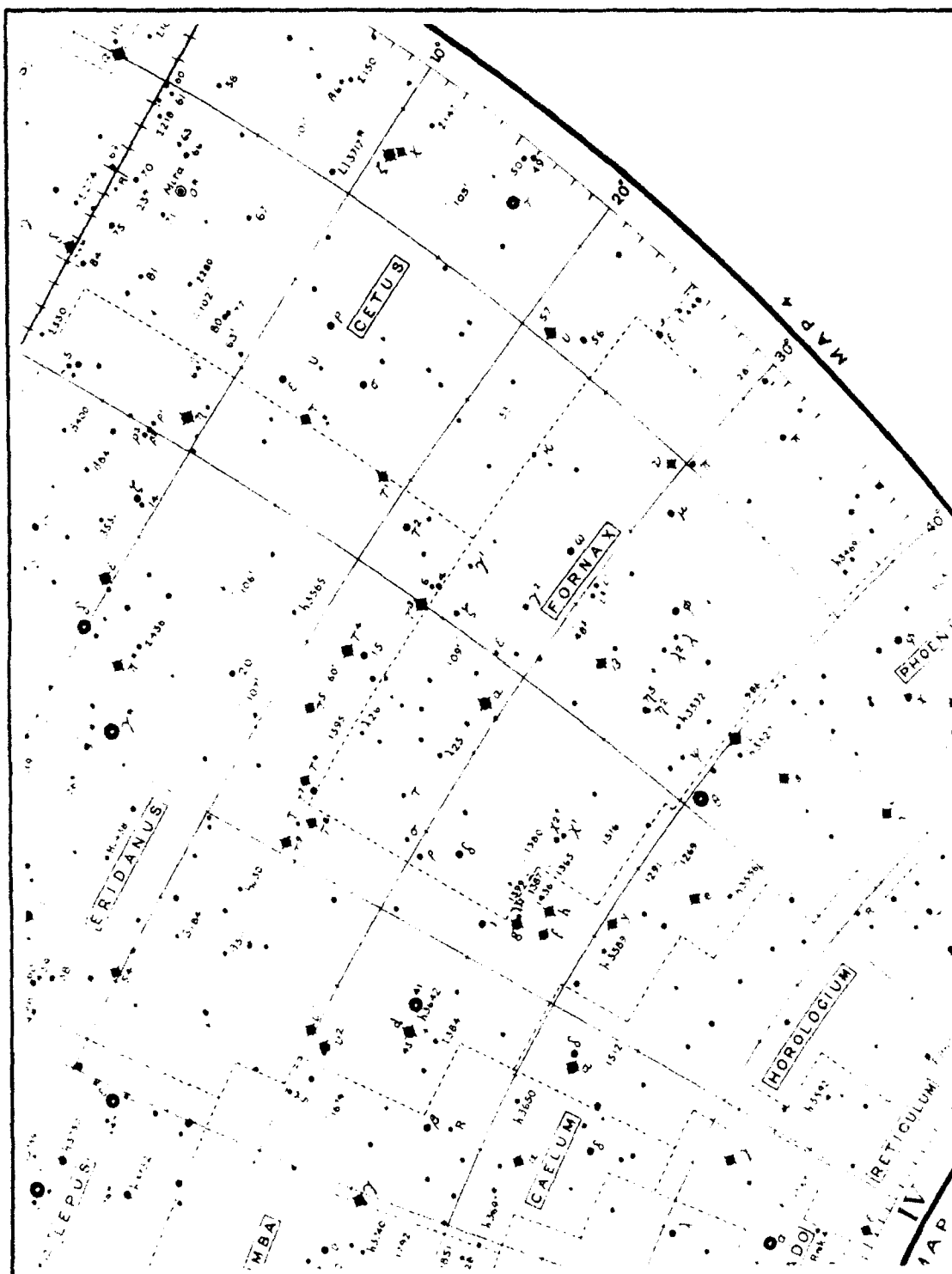
## APPENDIX C

### CRRES-CARIBBEAN GEOGRAPHICAL COORDINATES

| <u>EVENT</u>           | <u>COORDINATES</u>                                  |
|------------------------|-----------------------------------------------------|
| AA-1                   | 18.8205 N. Lat.<br>66.7152 W. Long.                 |
| AA-7                   | 18.9142 N. Lat.<br>66.7963 W. Long.                 |
| AA-2                   | 18.8231 N. Lat.<br>66.6385 W. Long.                 |
| GRAND TURK OPTICS SITE | 21.48 N. Lat.<br>71.13 W. Long.<br>45 ft. Elevation |

APPENDIX D

STAR FIELD BACKGROUND



Celestial Background and Orientation for Event AA-1 Data.